S.Chandrashekhar Reddy , P.V.N.Prasad, A.Jaya Laxmi / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 3, May-Jun 2012, pp.3077-3082

Optimal Number and Location of DGs to Improve Power Quality of Distribution System Using Particle Swarm Optimization

S.Chandrashekhar Reddy
Associate Professor,
Department of EEE,
Christu Jyoti Institute of Technolgy & Science
Jangaon, Warangal, Andhra Pradesh

P.V.N.Prasad
Professor,
Department of EE,
University College of Engg.
Osmania University,Hyderabad

A.Jaya Laxmi
Associate Professor,
Department of EEE,
J.N.T.U.H College of Engg,
J.N.T.University,Hyderabad

Abstract—Distributed Generators (DGs) are now commonly used in distribution systems to reduce the power disruption in the power system network. Due to the installation of DGs in the system, the total power loss can be reduced and voltage profile of the buses and reliability of the system can be improved. The significant process to decrease the total power loss and to improve the power quality of the system is to identify the optimal number of DGs and their suitable locations in the system. To accomplish the aforementioned process and to evaluate the amount of power to be generated, a new method is proposed using Particle Swarm Optimization. The proposed method is tested for IEEE 30 bus system, by connecting optimal number of DGs in the system. The results showed a considerable reduction in the total power loss in the system and improved voltage profiles of the buses.

***Keywords*—DG, PSO, Power Loss and Voltage Profile.**

I. INTRODUCTION

In current years, a lot of work has already been done in the electric power system infrastructure and market related to it by using Distribution Generation. Distributed Generation, is usually defined as a small-scale power generation facility that is usually connected or installed to the distribution system While on the other hand to reduce the cost of service, the DGs usually use different modular technologies which are located around a utility's service area. Distributed generation is a technique, which minimizes the amount of power loss in transmission lines by generating the power very close to load centre or maybe even transmitted in the same building.

In present times, use of DG systems in large amounts in the different power distribution systems have become very popular and is growing on with fast speed [1]. Some of the main advantages while installing DG units in distribution level are peak load saving, enhanced system security and reliability, improved voltage stability, grid strengthening, reduction in the on-peak operating cost, reduction in network loss etc. [2] [3]. The improvements in the reliability of the distribution network have come out as one of the most important benefits [4]. DGs are applied in the different power distribution systems because of energy efficiency or rational use of energy, deregulation or competition policy, diversification of energy sources, availability of modular generating plant, ease of finding locations for smaller generators, shorter construction time and lower capital costs comparatively for smaller plants, and its proximity of the generation plant to heavy loads, which reduces the transmission costs [5].

A lot of technologies are used for DG sources such as photo voltaic cells, wind generation, combustion engines, fuel cells and there are some other types of generation from the natural or artificial resources that are available in the geographical area [6][7]. Usually, DGs are attached with the already existing distribution system and lot of studies are performed to find out the best location and size of DGs to produce highest benefits [8][9]. The different characteristics that are considered to identify an optimal DG location and size are the minimization of transmission loss, maximization of supply reliability, maximization of profit of the distribution companies etc [10].

Due to wide-ranging costs, the DGs are to be allocated properly with best size to enhance the performance of the system in order to minimize the loss in the system as well as to get some improvements in the different voltage profiles while we also have to maintain the stability of the system [11]. The effect of placing a DG on network indices will be different based upon its type and location and (predict) load at the connection point [12]. There are lot of variety of potential benefits to DG systems both to the consumer and the electrical supplier that allow for both greater electrical flexibility and energy security [13].

In this paper, the optimal placement of DG and amount of power being generated by DG are computed using PSO and neural network. Here, authors presented a two stage PSO and one stage neural network which is used to identify the optimal placement of DG and amount of power to be generated. By using this method, the total power loss in the system is reduced and reliability of the system increases. The rest of the paper is organized as follows: Section II briefly reviews the recent related works; Section III describes the proposed technique with sufficient mathematical models and illustrations; Section IV discusses the implementation results; and Section V concludes the paper.

II. Related Researches: A Review

Some of the latest research regarding optimal location and the reliability of distributed generator are as follows.

Amanifar *et al*. [14] have proposed a PSO algorithm that finds out the optimal placement and size of DGs and this proposed method was performed on a 15- bus test system. One of their objectives was to get some reduction by considering some functions such as total cost of the system, real power loss and the number of DGs to be connected. The objective function depends on some operating constraints. The obtained simulation results have proved that DG in optimum location and sizing can result into minimization of the fiscal cost. The number of DGs effect goodly to reduce the fiscal cost. Moreover, the result has indicated that the PSO have the potential to search for the best position and size of DGs on power system network. Also, the best DG placement and sizing result in enhancement of voltage profile, diminution of power losses and improvements are produced in power transfer capacity.

Yassami *et al.* [15] have suggested a Pareto based Multi-objective Optimization Algorithm (MOA) known as Strength Pareto Evolutionary Algorithm (SPEA) for DG planning in different distribution networks. In opposition to the conventional multi-objective optimization techniques this technique correlate different objective functions by utilizing their weighting coefficients and by creating one single objective function. In SPEA, each objective function is optimized separately. As the most of the objective functions are in contrast with each other, the SPEA produces a set of optimum solutions on the place of one single optimum one. Three different objective functions considered are: (1) minimization of power generation cost (2) minimization of active power loss (3) maximization of reliability level. The goal of this optimization is to achieve each objective function. The site and size of DG units are assumed as design variables.

Injeti *et al.* [16] have proposed a technique for optimal planning and operation of different active distribution networks regarding the location and sizing of Distributed Generators. The DG unit placement and sizing is calculated by using a fuzzy logic and an analytical method respectively. The efficiency of the proposed method is to produce a comprehensive performance analysis on 12-bus, 33-bus and 69-bus radial distribution networks.

Mohammadi *et al.* [17] have proposed an optimal DG unit placement using Genetic Algorithm (GA). The best possible size of the DG unit is calculated analytically by using approximate reasoning suitable nodes that are determined for DG unit placement. Reliability and power loss reduction indices of distribution system nodes are modeled. GA containing a set of rules is used to determine the DG unit placement. DG units are placed with the highest suitability index. Simulation results have shown the advantage of optimal DG unit placement. In comparison with the other power loss and reliability improvement techniques, it is providing very good reduction not only in power loss but also it is improving reliability improvement.

In order to produce some reductions in the real power losses and to make some enhancements in the voltage profile, Lalitha *et al*. [18] have suggested a Fuzzy and PSO technique to install DG in the radial distribution systems. A two-stage methodology has been proposed for the optimal DG placement: (1) In the first stage, the best DG location was found out by using fuzzy approach, and (2) In the second stage, the size of the DGs is found by using PSO for maximum loss reduction.

Paliwal *et al*. [19] have investigated the different impacts of DG unit's installation on different criterions such as, electric losses, reliability and voltage profile of distribution networks. Their aim of this study is to find optimal distributed generation allocation for loss reduction subjected to constraint of voltage regulation in distribution network. The system is further analyzed for different increased levels of Reliability. Distributed Generator offers the additional advantage of increasing reliability levels as suggested by the improvements in various reliability indices such as SAIDI, CAIDI and AENS. Comparative studies are carried out and related results are addressed.

A. Rezazadeh *et al*. [20] have shown the different impacts of DG on the power system transitory stability. They have used a typical 6-bus power system in their relative study of this technique. They have considered many different-2 scenarios to investigate genetic algorithm to allocate and sizing of DGs. After occurrence of a fault and tripping faulty line, power in the slack bus generator changes comprehensively in order to compensate for the losses of new power flow route. These changes of power produced in each case with no DG are calculated and compared with summation of DG sizes.

III. Identifying optimal number of DGs to be connected using PSO

To reduce the total power losses in the distribution system, Distributed Generators (DGs) are used. The major challenges that occur while using DG are identifying the optimal number of DGs and their locations and also the amount of power to be generated by each DG. The proposed technique used is Particle Swarm Optimization. The process that takes place in the proposed method is explained briefly in the below sections and the overall process is depicted in the following flow chart shown in Figure 1.

A. Power Flow Computation using NR method

In this proposed method, Newton Raphson method is used to calculate the power flow between the buses. Newton Raphson method is a commonly used method, to calculate the power flow because it takes less number of iterations. The real and reactive power flows between the buses are computed using the equations 1 & 2.

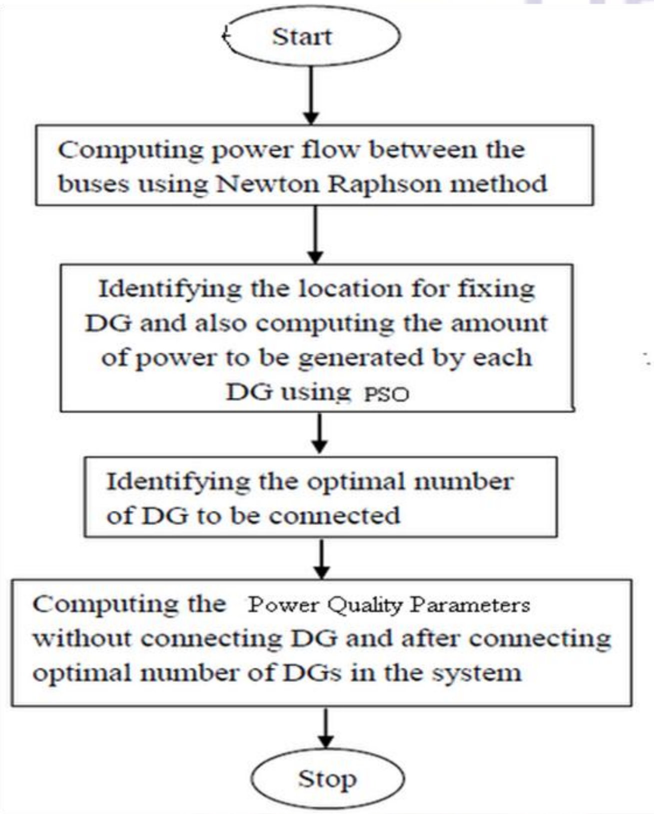

Figure 1. Overall process in the proposed method

$$P_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \cos\theta_{ik} + B_{ik} * \sin\theta_{ik} \right) \quad (1)$$

$$Q_i = \sum_{k=1}^{N} V_i * V_k \left(G_{ik} * \sin\theta_{ik} - B_{ik} * \cos\theta_{ik} \right) \quad (2)$$

where, N is the total number of buses, V_i & V_k are the voltage at i & k bus respectively, θ_{ik} is the angle between i & k bus, and G_{ik} & B_{ik} are the conductance and susceptance values respectively.

The real and reactive power flow between the buses mainly depends on the voltage and angle values. After calculating the real and reactive powers between the buses, the next step is to calculate the optimal location for fixing DGs in the system. In the proposed method PSO is used for generating training dataset to obtain optimal locations.

B. Generating Training Dataset for Fixing DG using PSO

The next step included after computation of the load flow between the different buses is identification of optimal location for placing DGs. Here, PSO is used in generation of training dataset. The training dataset is mostly generated for possible connection for fixing one, two, three and four DGs in the system, and the best set of combinations are selected on the basis of the power losses of the system. The set of best combination of DGs are selected based on the total power losses in the system. Normally, PSO consists of four different stages namely, generating initial particle, evaluation function, updating initial particle and termination.

1) Generating initial particle

Initial process related to the generation of training dataset using PSO is generating initial particle. Let D_n be the input initial particle and $\{P_n, Q_n, L_n\}$ be the output initial particle. The initial chromosomes are generated within a certain limit. The limits for generating initial chromosome are $1 \le D_n \le N$, $P^{min} \le P_n \le P^{max}$, $Q^{min} \le Q_n \le Q^{max}$ & $1 \le L_n \le M$. where N is total no. of DG_S to be connected and M be the total no. of buses.

2) Evaluation function

Evaluation function is used in PSO to identify the best particle from the set of initialized particle. The evaluation function used in our method is total power loss.

$$P_{loss} = \sum_{i,j=1}^{N} \mathrm{Re}\,al\left[Conj\left((V_m(i)) * (V_m(j)) \right) * Y_{ij} * B \right] \quad (3)$$

where, V_m is the voltage magnitude, Y_{ij} is the Y-bus matrix and B is the base MVA value.

By using equation 3, the total power losses in the system are computed and based on the total power loss, the best location for placing the DG is identified.

3) Updating initial particle

Updating the different particles in the system is an important process in PSO. In this stage, the initial particles are generated are updated and the evaluation function is computed. The particles are updated using the equation given below.

$$v[\,] = v[\,] + c1 * rand() * (\mathrm{pbest}[\,] - \mathrm{present}[\,]) + c2 * rand() * (gbest[\,] - present[\,]) \quad (4)$$

$$present[\,] = present[\,] + v[\,] \quad (5)$$

where, $v[\,]$ is the particle velocity, $present[\,]$ is the current particle, $pbest[\,]$ and $gbest[\,]$ are the best fitness values and best values for any particle in the population respectively, $rand()$ is the random number between $(0,1)$ and $c1$, $c2$ are learning factors.

(4) Termination

In the termination stage, best particles are on the basis of the evaluation function. Here based on the evaluation function different possible DG connecting location was computed. The above process is repeated until the best particle obtained. After completion of termination process, a possible set of location for fixing DGs and their corresponding real and reactive power values are obtained. The above process is repeated for different number of DGs connected in the system.

The training dataset generated using first stage PSO is shown below.

$$D = \begin{bmatrix} DG_P^{\ 1} \\ DG_P^{\ 2} \\ . \\ . \\ DG_P^{\ r} \end{bmatrix} \begin{bmatrix} B_P^{\ 1}, P_P^{\ 1}, Q_P^{\ 1} \\ B_P^{\ 2}, P_P^{\ 2}, Q_P^{\ 2} \\ . \\ . \\ B_P^{\ r}, P_P^{\ r}, Q_P^{\ r} \end{bmatrix} \quad (6)$$

The above dataset is generated for different possible locations for connecting 1, 2,… r DGs and from the possible bus combination the best set of locations are taken as the dataset and from this dataset the best location is identified using neural network.

C. Identifying the optimal number of DGs to be connected in the system

From the above generated dataset using Particle Swarm Optimization, the optimal number of DGs to be connected in the system is identified based on the total power loss of the system. Normally, the total power loss is reduced by connecting DG in the system. If the number of DGs connected in the system is increased, then the total power loss will reduces considerably. For finding the optimal number of DGs, check the power loss after each number of DG connected in the system. If the power loss is increased than the previous value, then consider that particular number of DGs connected in the system till the power loss reduces as the optimal number of DGs to be connected in the system.

For identifying the optimal number of DGs, initially, the total power loss obtained after connecting one DG in the system is computed and then the total power loss obtained after increasing the DG as two, three, and more are also computed. After increasing the number of DG, check the total power loss and if the power loss is less than the above loss, then increase the number of DGs. This process repeats until the total power loss reaches higher than the previous loss value and that number of DGs is considered as the optimal number of DGs to be connected in the system.

IV. Result and Discussion

The proposed method is implemented using MATLAB 2011 and tested for IEEE 30 bus system. which is shown in Figure 2. In this system, bus 1 is considered as the slack bus, buses 2, 13, 22, 23 & 27 are generator buses and there are 41 transmission lines in total. There are loads in 20 nodes, i.e., bus 2, 3, 4, 7, 8, 10, 12, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 26, 29 and 30 [21]. The buses are connected in loop thus it is considered as a power system that operates under 11 KV levels [22]. The active and reactive power of each unit of DG is randomly generated within the power limits of $0 \le P \le 10$ MW and $3 \le Q \le 7$ MVAR respectively. The proposed method is tested for 283.4 MW load and the optimal number of DGs to be connected in the system identified is found to be 6. The best location for fixing 6 DGs and the amount of power to be generated by these DGs are identified and is shown in Table 1. Table 2 shows the per unit bus voltage profiles after installing six DGs in the system network.

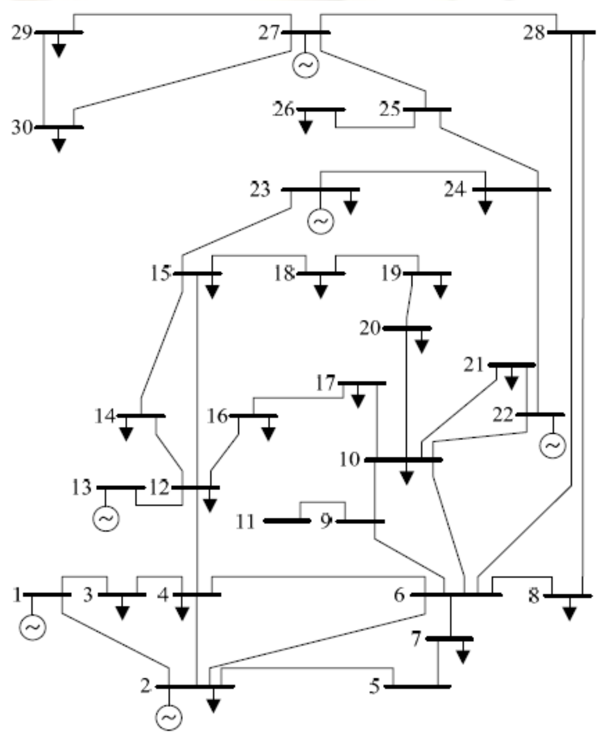

Figure 2. IEEE 30 bus system

In the test system, bus 1 is considered as the slack bus and the base MVA of the system is 100. Bus 2, 13, 22, 23 and 27 are generator buses and the remaining all other buses are load buses.

Table-1 Optimal location and Active Power of each DG Unit

Optimal location identified using proposed method	Amount of power generated by each DG identified using proposed method (MW)
9	5.9749
21	7.3091
23	7.4703
5	9.3885
8	7.9895
19	6.2984

Table-2 Voltage Comparison at total load of 283.4 MW

Bus number	Per Unit Voltages at each bus	
	Without DG	With Six DGs
1	1.0600	1.0600
2	1.0430	1.0430
3	1.0277	1.0326
4	1.0198	1.0255
5	1.0100	1.0100
6	1.0173	1.0220
7	1.0066	1.0094
8	1.0100	1.0100
9	1.0540	1.0672
10	1.0469	1.0672
11	1.0516	1.0820
12	1.0620	1.0711
13	1.0451	1.0710
14	1.0474	1.0609
15	1.0426	1.0614
16	1.0483	1.0623
17	1.0420	1.0605
18	1.0320	1.0587
19	1.0288	1.0602
20	1.0326	1.0611
21	1.0333	1.0621
22	1.0451	1.0663
23	1.0334	1.0625
24	1.0310	1.0534
25	1.0278	1.0431
26	1.0103	1.0258
27	1.0356	1.0451
28	1.0169	1.0216
29	1.0160	1.0257
30	1.0047	1.0145

From the Table 2, it is clear that, with optimal location of six DGs in the system, the voltage profile of all buses remained stable within tolerable limits.

Table-3 Power loss comparison at 283.4 MW

Performance Parameters	Without DG	With Six DGs	% Reduction
Total Power loss (MW)	10.563	6.661	37

The total power loss at without DG is 10.563 MW and the total power loss after connecting the optimal number of DGs in the system is 6.661 MW. Thus there is a reduction by about 37% of total power losses in the system. The graphical representations of total power loss with respect to No.of DGs are shown in Figure 3.

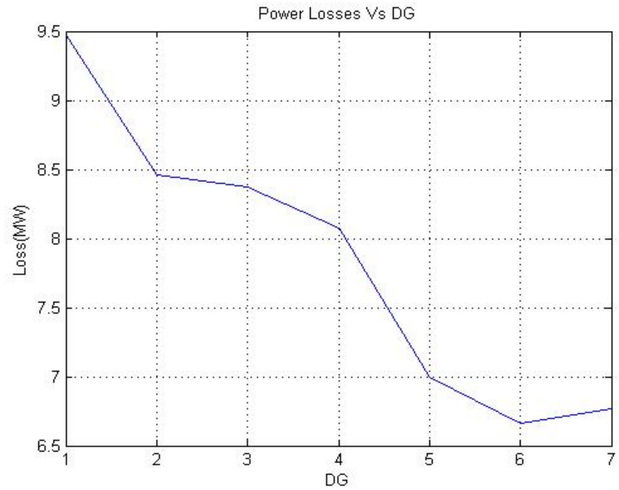

Figure 3. Power losses Vs No. of DGs

The per unit voltage profiles of all the buses are shown in Table 2 at a load of 283.4 MW. After connecting optimal number of DG_s in the system, the bus voltages remain stable within permissible limits.

V. CONCLUSION

In this paper, optimal number of DGs and their locations using Particle Swarm Optimization was tested for a IEEE 30 bus system. The comparison was made without and with DGs in terms of total power loss and voltage profile of all the buses. The optimal number of DGs to be connected in the system was identified as six and these DGs should be located on the buses 5, 8, 9, 19, 21 and 23 for minimization of total power loss. The total power loss in without DG was 10.563 MW and after connecting DGs in the system, the power loss was reduced to 6.661 MW. Thus the total loss was reduced to 37% of total power losses in the system and the voltage profile of all the buses remained stable within the tolerable limits. Hence, the power quality of the system increases.

REFERENCES

[1] Mansooreh Zangiabadi, Rene Feuillet and Hamid Lesani, "An Approach to Deterministic and Stochastic Evaluation of the Uncertainties in Distributed Generation Systems", In Proceedings of 20th International Conference on Electricity Distribution, pp. 1-4, Prague, 2009.

[2] Rashid H. Al-Rubayi and Azhar M. Alrawi, "Optimal Size and Location of Distributed Generators using Intelligent Techniques", Engg. & Tech. Journal, Vol. 28, No. 23, pp. 6623-6633, 2010.

[3] M.F. Akorede, H. Hizam, I. Aris and M.Z.A. Ab Kadir, "A Review of Stratergies for Optimal Placement of Distributed Generation in Power Distribution Systems", Research Journal of Applied Sciences, Vol. 5, No. 2, pp. 137-145, 2010.

[4] Paulo Moises Costa and Manuel A. Matos, "Assessing the contribution of microgrids to the reliability of distribution networks", Electric Power Systems Research, Vol. 79, pp. 382–389, 2009.

[5] M.Padma Lalitha, V.C. Veera Reddy, N.Sivarami Reddy and V.Usha Redddy, "A Two Stage Methodology for Siting and Sizing of DG for Minimum Loss in Radial Distribution System using RCGA", International Journal of Computer Applications, Vol. 25, No.2, pp. 10-16, 2011.

[6] K. Manjunatha Sharma and K. P. Vittal, "A Heuristic Approach to Distributed Generation Source Allocation for Electrical Power Distribution Systems", Iranian Journal of Electrical & Electronic Engineering, Vol. 6, No. 4, pp. 224-231, Dec. 2010

[7] M.F.Kotb, K.M.Shebl, M. El Khazendar and A. El Husseiny, "Genetic Algorithm for Optimum Siting and Sizing of Distributed Generation", In Proceedings of 14th International Middle East Power Systems Conference, pp. 433-440, Egypt, 2010.

[8] Deependra Singh, Devender Singh and K S Verma, "Distributed Generation Planning Strategy with Load Models in Radial Distribution System", International Journal of Computer and Electrical Engineering, Vol. 1, No. 3, pp. 362-375, Aug 2009.

[9] Wichit Krueasuk and Weerakorn Ongsakul, "Optimal Placement of Distributed Generation using Particle Swarm Optimization", In Proceedings of Power Engineering Conference in Australasian Universities, Australia, 2006.

[10] Soma Biswas and S.K. Goswami, "Genetic Algorithm based Optimal Placement of Distributed Generation Reducing Loss and Improving Voltage Sag Performance", Proc. of Int. Conf. on Advances in Electrical & Electronics, pp. 49-51, 2010.

[11] Naveen Jain, S.N. Singh and S.C. Srivastava, "Particle Swarm Optimization Based Method for Optimal Siting and Sizing of Multiple Distributed Generators", In Proceedings of 16th National Power Systems Conference, pp. 669-674, Hyderabad, 2010.

[12] Amin Hajizadeh, Ehsan Hajizadeh, "PSO-Based Planning of Distribution Systems with Distributed Generations", International Journal of Electrical and Electronics Engineering, Vol. 2, No. 1, pp. 33-38, 2008.

[13] Benjamin Kroposki, Christopher Pink, Richard DeBlasio, Holly Thomas, Marcelo Simoes and Pankaj K. Sen, "Benefits of Power Electronic Interfaces for Distributed Energy Systems", IEEE Transactions on Energy Conversion, Vol. 25, No. 3, pp. 901-908, Sep 2010.

[14] O. Amanifar and M.E. Hamedani Golshan, "Optimal Distributed Generation Placement and Sizing for Loss and THD Reduction and Voltage Profile Improvement in Distribution Systems using Particle Swarm Optimization and Sensitivity Analysis", International Journal on Technical and Physical Problems of Engineering, Vol. 3, No. 2, pp. 47-53, 2011.

[15] H. Yassami, A. Moeini, S. M. R. Rafiei, A. Darabi and A. Bagheri, "Optimal distributed generation planning considering reliability, cost of energy and power loss", Scientific Research and Essays, Vol. 6, No.9, pp. 1963-1976, May 2011.

[16] S. Kumar Injeti and Navuri P Kumar, "Optimal Planning of Distributed Generation for Improved Voltage Stability and Loss Reduction", International Journal of Computer Applications, Vol. 15, No.1, pp. 40-46, Feb 2011.

[17] Mohammad Mohammadi and M. Akbari Nasab, "DG Placement with Considering Reliability Improvement and Power Loss Reduction with GA Method", Research Journal of Applied Sciences, Engineering and Technology 3(8): 838-842, 2011

[18] M. Padma Lalitha, V.C. Veera Reddy, N. Sivarami Reddy and K. Sivagangadhar Reddy, "Clonal Selection Algorithm for DG Sources Allocation for Minimum Loss in Distribution System", International Journal of Computer Science & Emerging Technologies, Vol. 1, pp. 85-91, Oct 2010.

[19] Priyanka Paliwal and N.P. Patidar, "Distributed Generator Placement for Loss Reduction and Improvement in Reliability", World Academy of Science, Engineering and Technology, Vol. 69, pp. 809-813, 2010.

[20] A. Rezazadeh M. Sedighizadeh and A. Alavian, "Optimal Sizing and Sitting of Distributed Generation for Power System Transient Stability Enhancement Using Genetic Algorithm", IACSIT International Journal of Computer Theory and Engineering, Vol. 1, No. 5, pp: 387-390, Dec 2009.

[21] Qing-Shan, Min XIE and Felix F.WU, "Ordinal Optimization Based Security Dispatching in Deregulated Power Systems", Joint 48th IEEE Conference on Decision and Control and 28th Chinese Control Conference, Shanghai, P.R.China, December 16-18,2009, FrA 15.4.[22]

[22] Samuel Raafat Fahim, Walid Helmy, Hany M.Hasanien and M.A.L.Badr, " Optimal Study of Distributed Generation Impact on Electrical Distribution Networks using GA and Generalized Reduced Gradient", Recent Researches in Communications, Electrical & Computer Engineering, pp. 77-82, 2001, ISBN: 978-960-474-286-8.